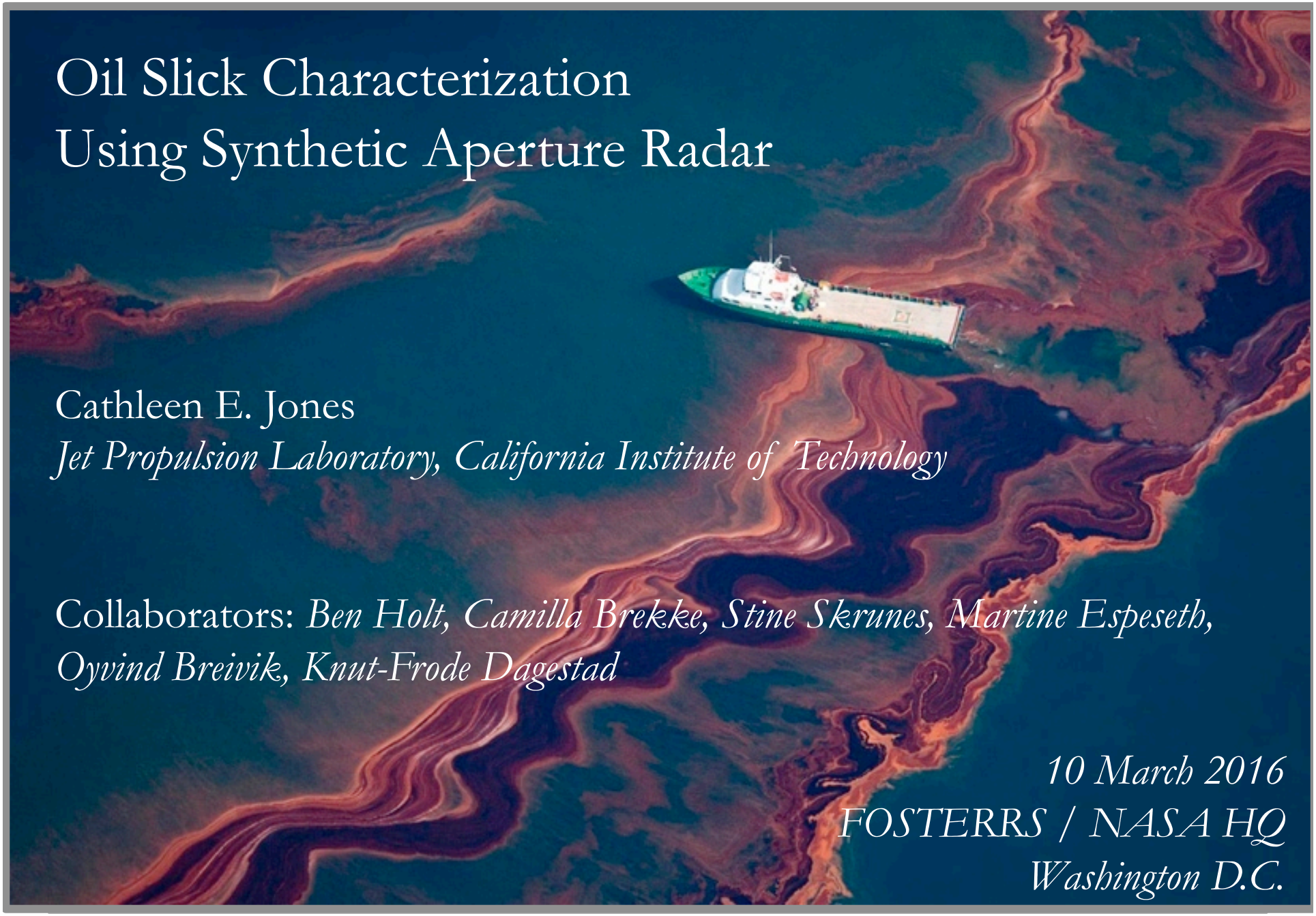
Oil Slick Characterization Using Synthetic Aperture Radar



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Collaborators: *Ben Holt, Camilla Brekke, Stine Skrunes, Martine Espeseth, Oyvind Breivik, Knut-Frode Dagestad*

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FOSTERRS / NASA HQ
Washington D.C.

Motivation

Effective response to oil spills requires specific information about the slick's characteristics:

Key Parameters:

- Oil spill position
- Slick type / origin
- Spill extent
- Spill thickness & volume
- Oil-to-water emulsion ratios
- Transport
- Weathering

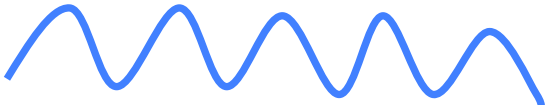
Oil / Water Dielectric Constant

Complex Permittivity
$\varepsilon = \varepsilon' - i\varepsilon''$

Sea water $\varepsilon_{sw} = 80 - i70$
-High conductivity surface

Crude oil $\varepsilon_O = 2.3 - i0.02$
-Low conductivity surface

Ocean Surface (no oil)



$\varepsilon_{SW} = 80 - i70$

-Frequency, temperature dependent

Ocean Surface +Thin Sheen

$\varepsilon_{SW+Sheen} \sim\sim 80 - i70$

-Reduced roughness
-Sheen too thin to change ε_{sw}

Emulsion = Mixture of Oil + Sea water

$\varepsilon_{Mixture} = \varepsilon_{SW} + \varepsilon_O$

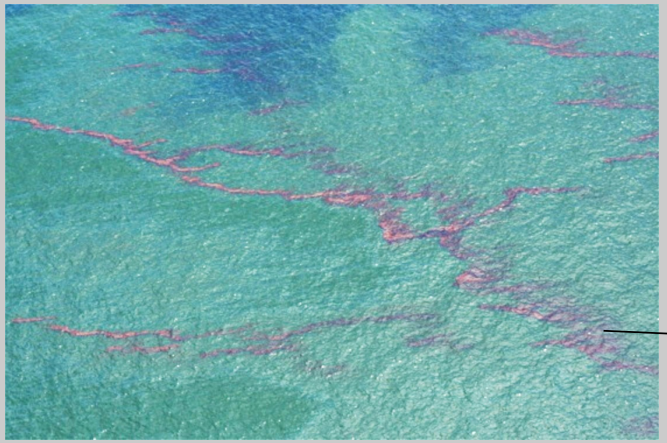
-New dielectric layer with ε mixture
–Alters scattering

Radar backscattered signal responds to volumetric fraction of emulsified oil as a mixture of oil and seawater

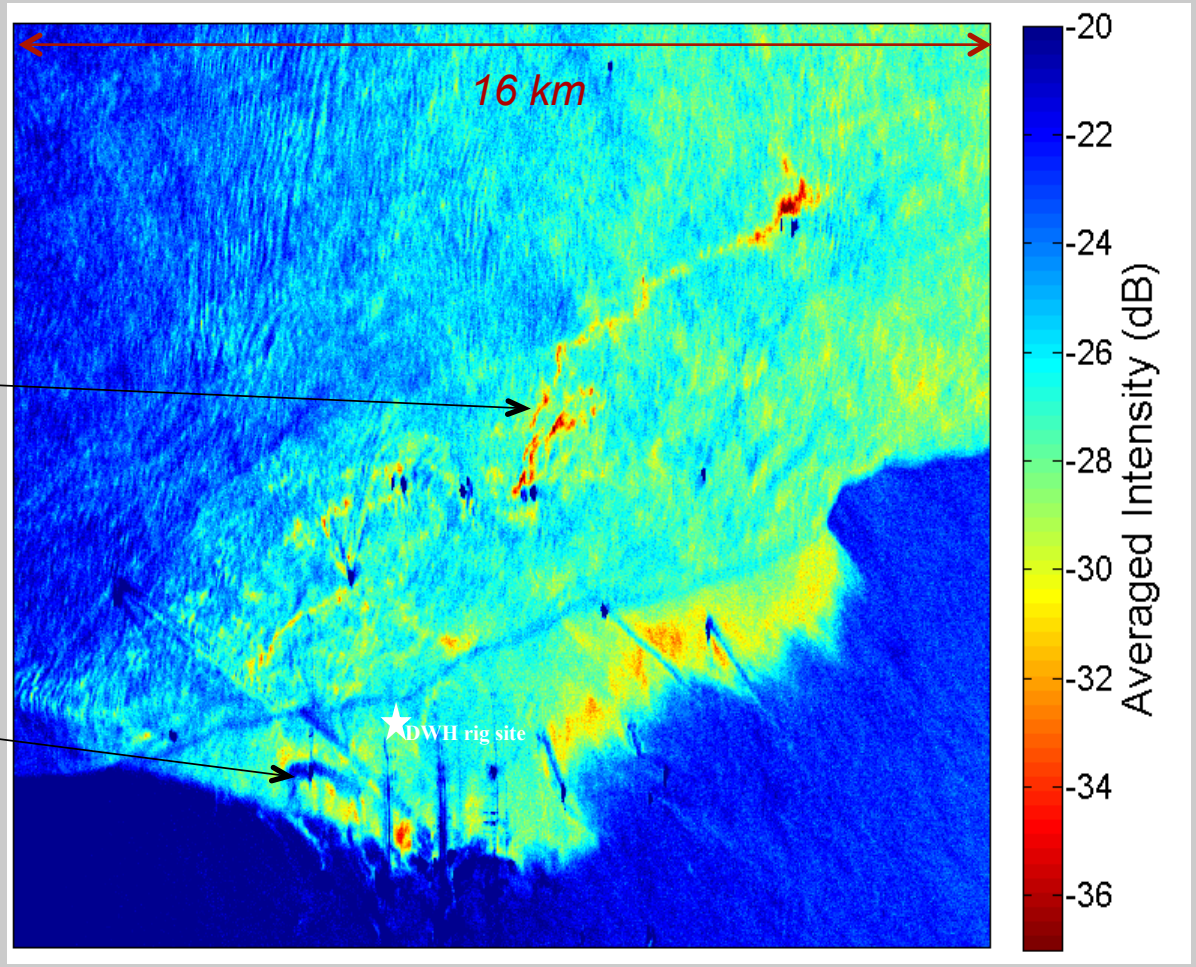
Oil Characterization with Radar Remote Sensing

From the NASA / UAVSAR Airborne Radar --- Deepwater Horizon Spill

Emulsion stringers:



Dispersants application:

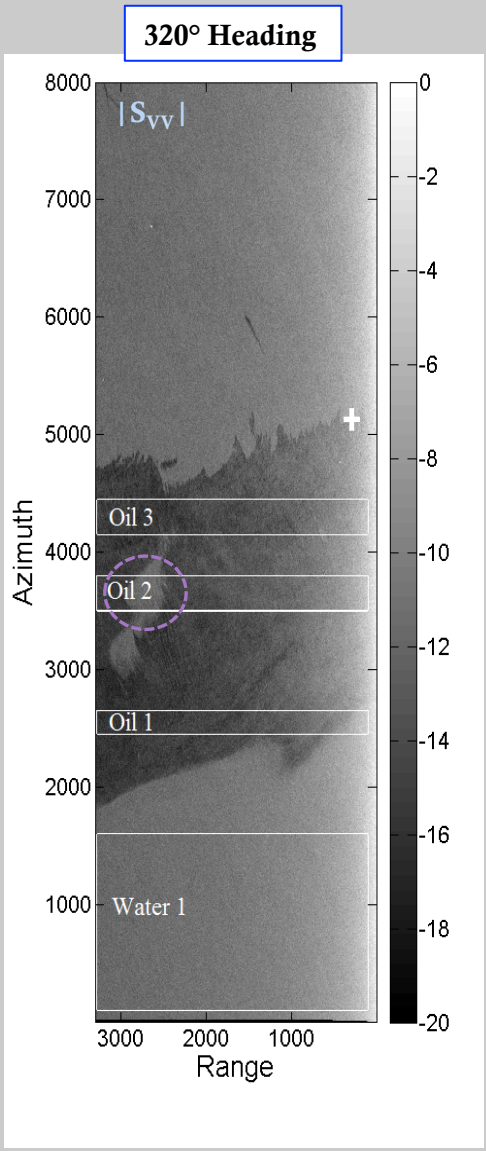


Photos taken over the slick on 6/23/2010 between 16:00 and 20:00 UTC (NOAA RAT-Helo and EPA/ASPECT)

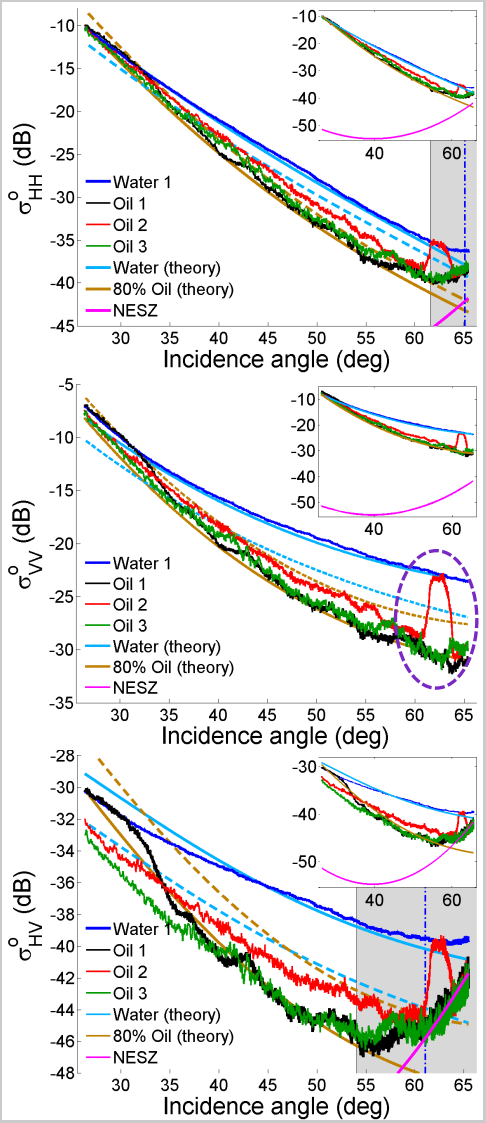
C. Jones, B. Holt, S. Hensley (JPL/Caltech), B. Minchew (Caltech), Studies of the Deepwater Horizon Oil Spill with the UAVSAR Radar, AGU Monograph Series, 2011.

Volumetric Concentration of Oil in Emulsion

From the NASA / UAVSAR Airborne Radar --- Deepwater Horizon Spill



Polarimetric Returns vs. Incidence Angle

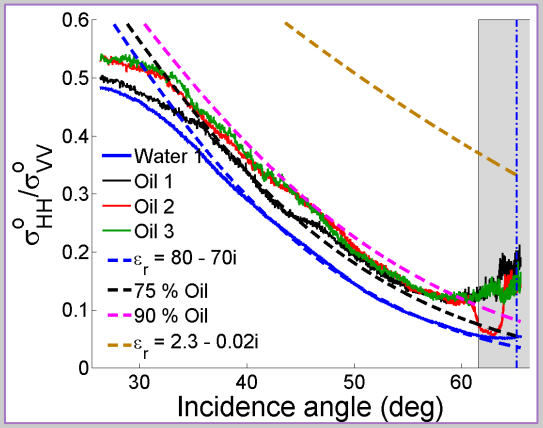


Bragg scattering theory describes well both scattering from clear water and from the oil slick.

We derive the volumetric concentration of oil within emulsion in the main oil slick using a fit for the dielectric coefficient within the Bragg scattering model.

For thick oil slicks we can estimate the volumetric oil concentration from the change in dielectric of the scattering surface.

Copolarized Ratio



B. Minchew, C. E. Jones, B. Holt, Polarimetric analysis of backscatter from the Deepwater Horizon oil spill using L-band radar, TGRS, 2012.

Norwegian Oil-on-Water Exercise 2015

9-11 June 2015 Oil-on-Water Controlled Release at the Frigg Field, North Sea, Norway

Day 2, controlled experiment for radar remote sensing

- Controlled releases of emulsions with a range of oil fractions
- Plant oil used as biogenic slick simulator
- All slicks left untouched on sea surface
- Radars used: UAVSAR/Radarsat-2/TerraSAR-X/ RISAT-1/ALOS-2

Collaborators: Camilla Brekke, Stine Skrunes, Øyvind Breivik (Norway), Ben Holt (JPL)

NORSE2015 – Satellite SAR & UAVSAR

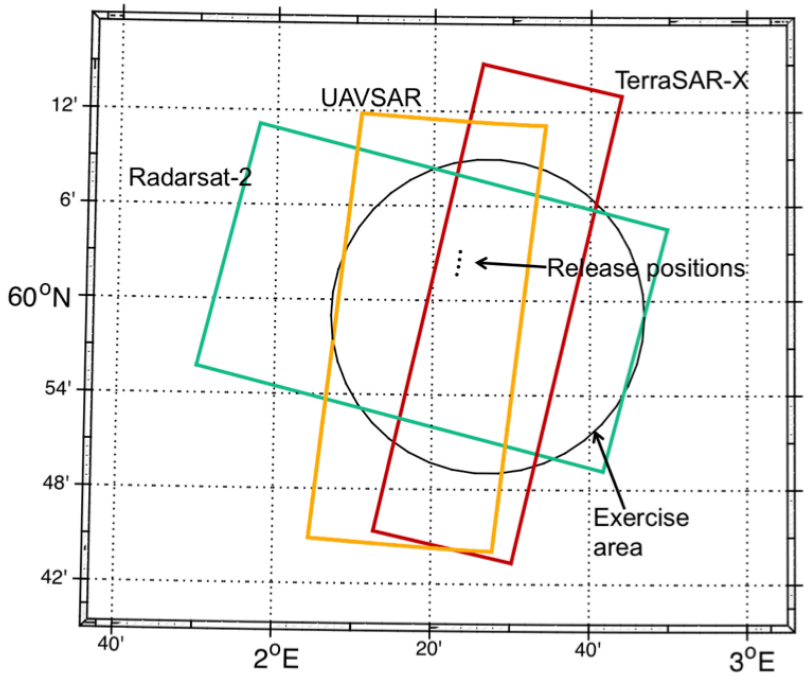
NORSE2015: Norwegian Spill Experiment (Day 2. 10 June 2015)

Release	Time (UTC)	Substance	Volume
P	04.48	Plant oil: Radiagreen ebo	0.2 m^3
E40	04.59	Emulsion (40% oil): 300 L water + 100 L Troll + 100 L Oseberg + 0.2 L One-Mul	0.5 m^3
E60	05.15	Emulsion (60% oil): 200 L water + 150 L Troll + 150 L Oseberg + 0.2 L One-Mul	0.5 m^3
E80	05.30	Emulsion (80% oil): 100 L water + 200 L Troll + 200 L Oseberg + 0.2 L One-Mul	0.5 m^3

Mineral oil:
3 barrels each

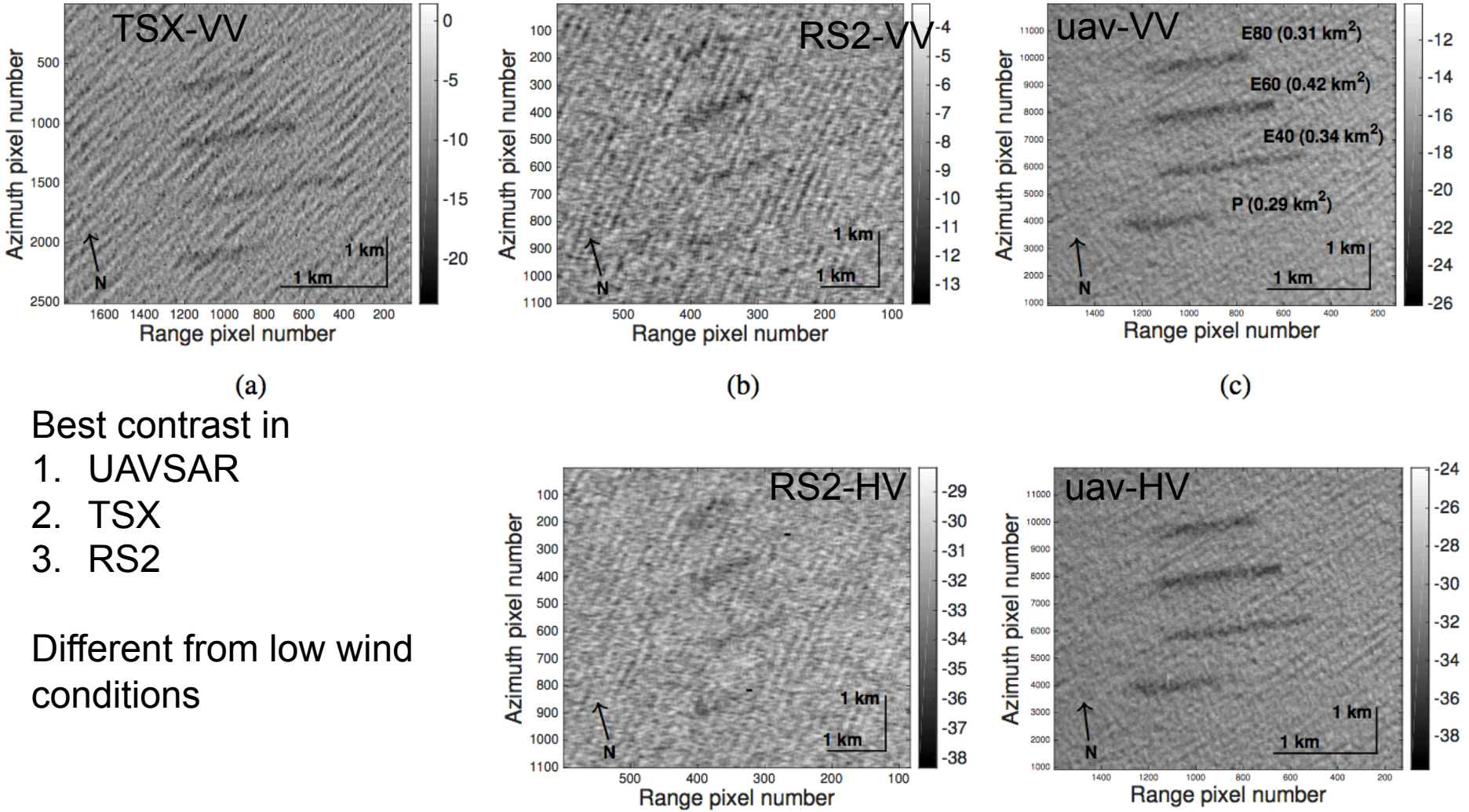
Sensor	Time (UTC)	Mode	Freq. band	Polarization
UAVSAR (16 scenes)	05.32-08.53	PolSAR	L-band	Quad-pol.
TSX	06.24	SM	X-band	Dual-pol. (HH, VV)
RS2	06.28	WFQ	C-band	Quad-pol.
RISAT-1	07.19	FRS	C-band	Compact pol. (RH, RV)
UAVSAR (6 scenes)	11.45-13.18	PolSAR	L-band	Quad-pol.
TSX	17.12	SM	X-band	Dual-pol. (HH, VV)
ALOS-2	23.53	HS	L-band	Single-pol. (VV)

UAVSAR: Repeated imaging of released slicks for ~8 hours following release



Satellite / Airborne SAR Comparison – 2015 Norway

Wind speed ca. 9 - 12 m/s



Best contrast in

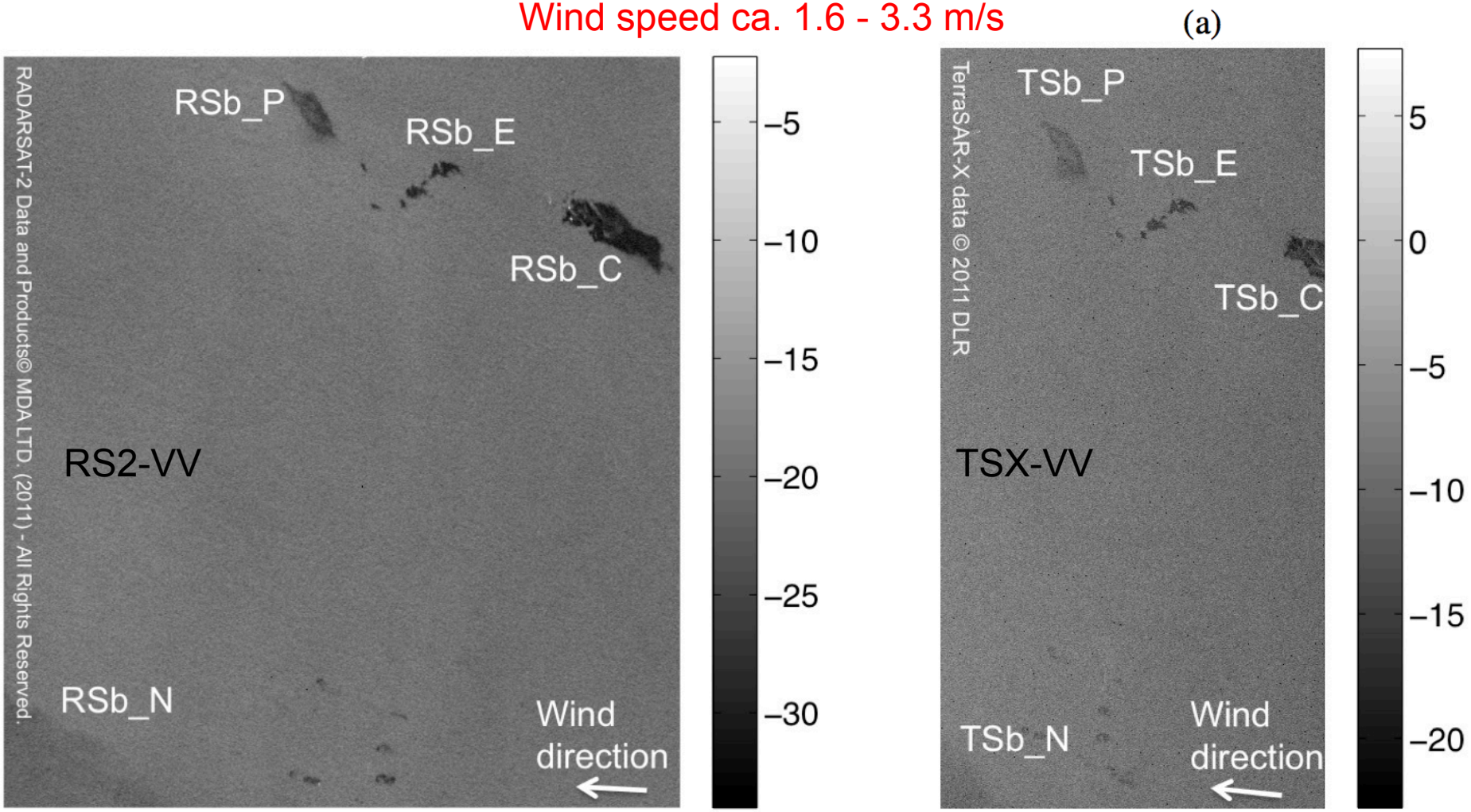
1. UAVSAR
2. TSX
3. RS2

Different from low wind conditions

Skrunes, S., Brekke, C., Jones, C., and Holt, B. (2015). A multisensor comparison of experimental oil spills in polarimetric SAR, *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of,* in review.

Satellite / Airborne SAR Comparison – 2011 Norway

Wind speed ca. 1.6 - 3.3 m/s



Skrunes, S., Brekke, C., Eltoft, T., & Kudryavtsev, V. (2015). Comparing near-coincident C-and X-band SAR acquisitions of marine oil spills. *Geoscience and Remote Sensing, IEEE Transactions on*, *53*(4), 1958-1975.

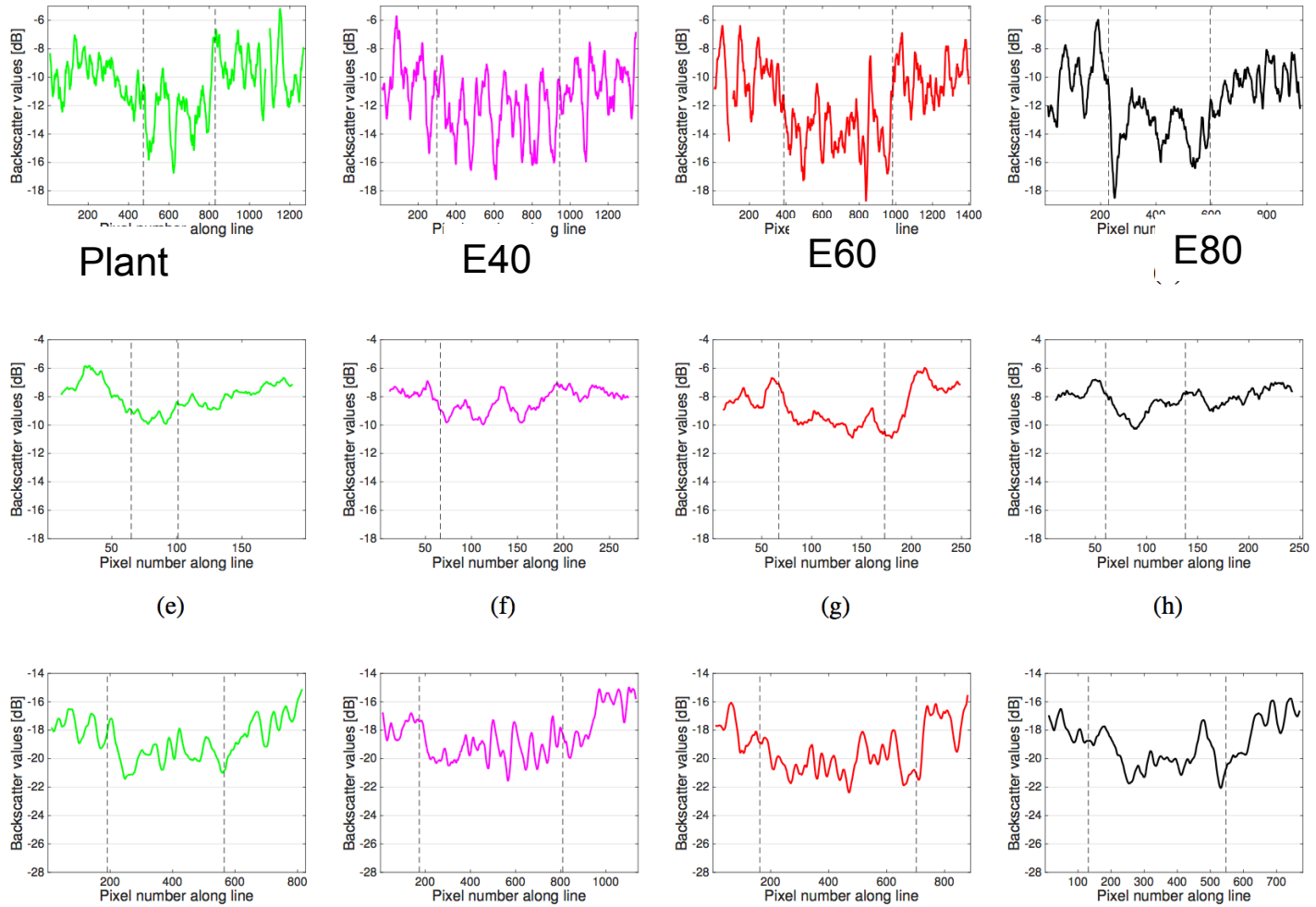
Slick / Clean Water Variation in Intensity with Frequency

400 pixel average profile:

TSX-VV

RS2-VV

uav-VV

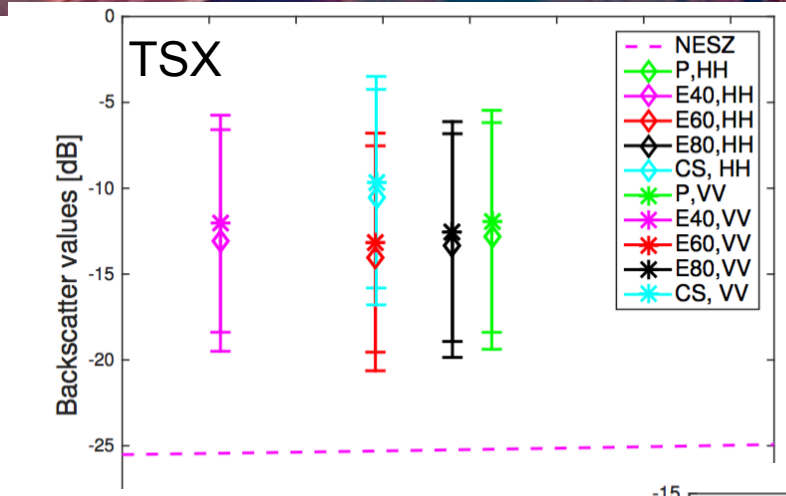


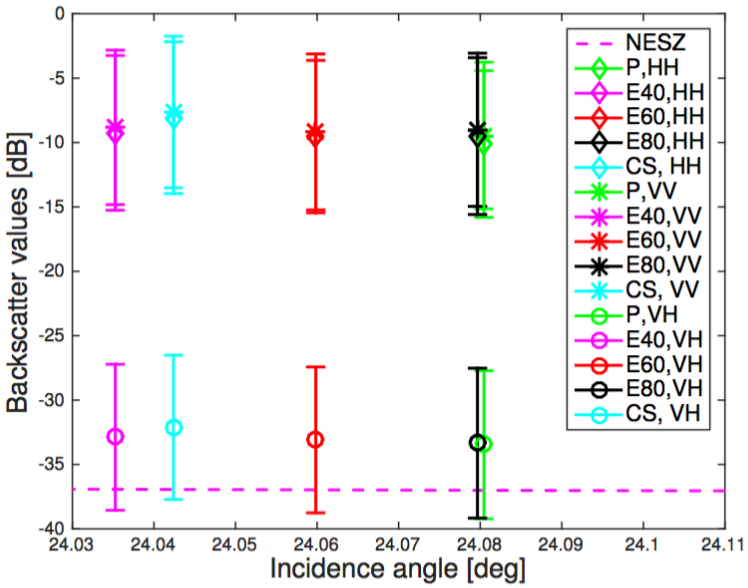
Wind speed ca. 9 - 12 m/s

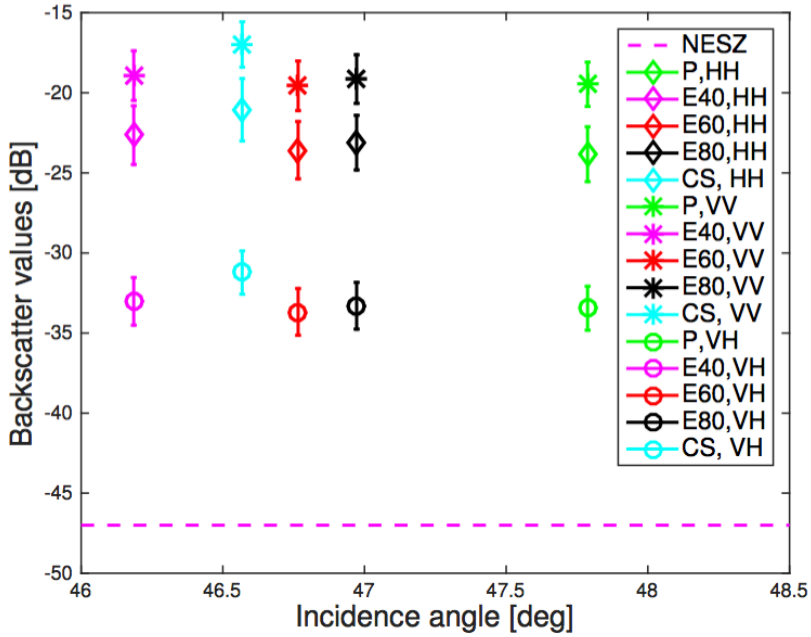
Skrunes, S., Brekke, C., Jones, C., and Holt, B. (2015). A multisensor comparison of experimental oil spills in polarimetric SAR, *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of,* in review.

Slick / Clean Water Single-Pixel Variability

Wind speed ca. 9 - 1



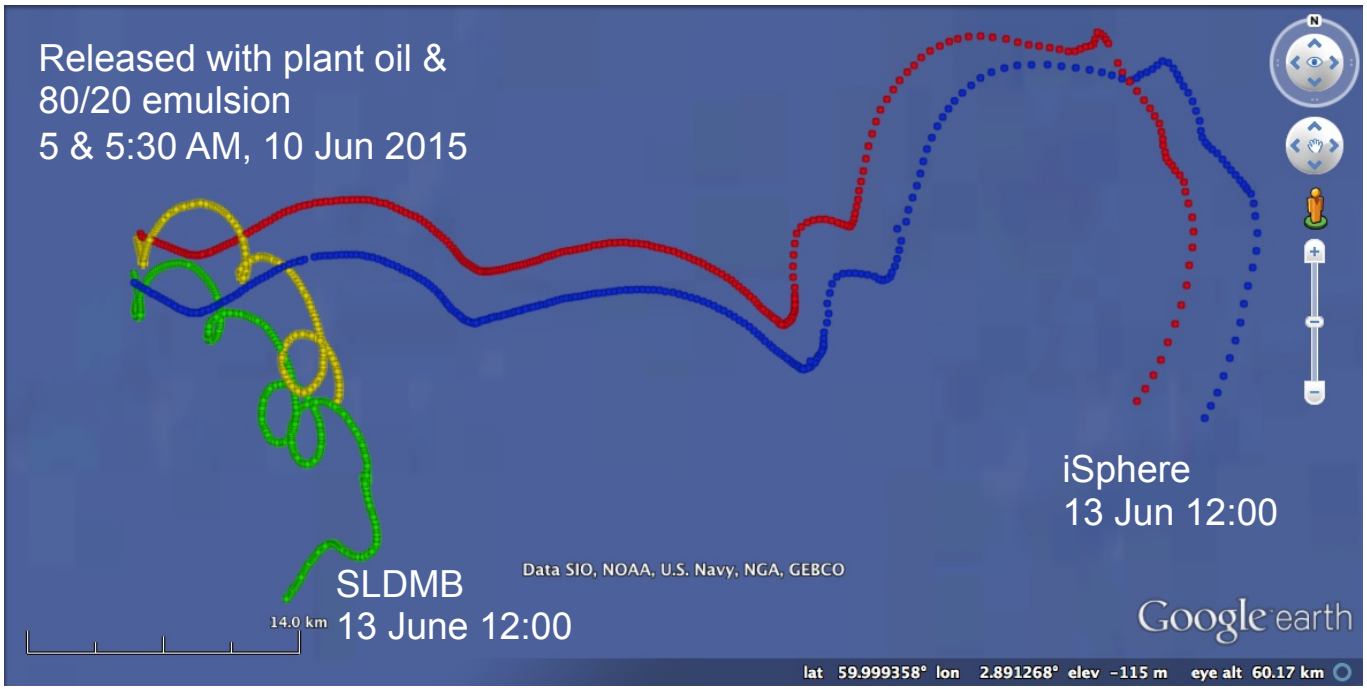




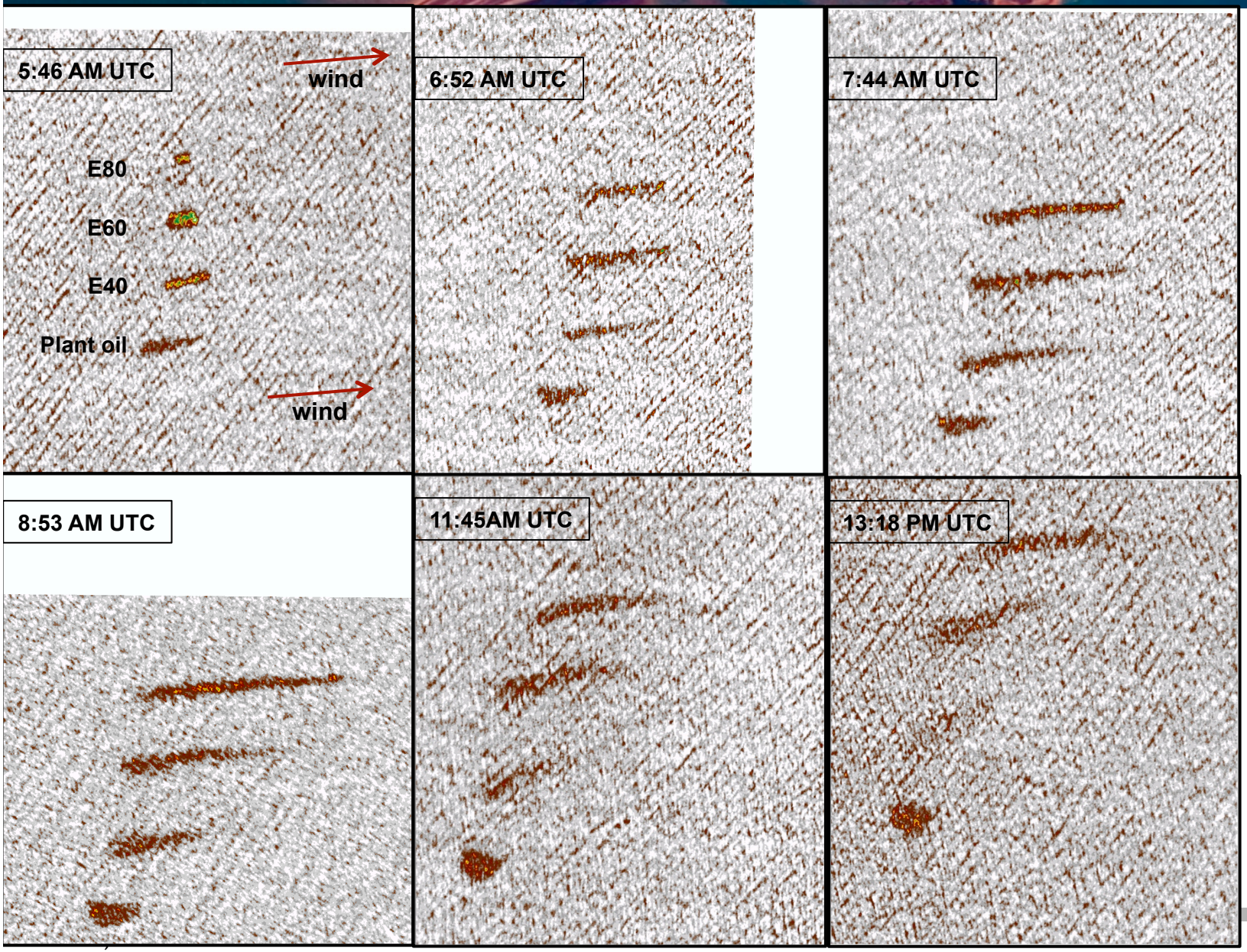
Skrunes, S., Brekke, C., Jones, C., and Holt, B. (2015). A multisensor comparison of experimental oil spills in polarimetric SAR, *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of,* in review.

Buoy / Drifter Data

Drifters:
2 iSphere (wind drift)
2 Self Locating Datum Marker Buoy (submerged)



Slick Development



$$\frac{\text{Intensity-VV}_{oil}}{\text{Intensity-VV}_{water}}$$

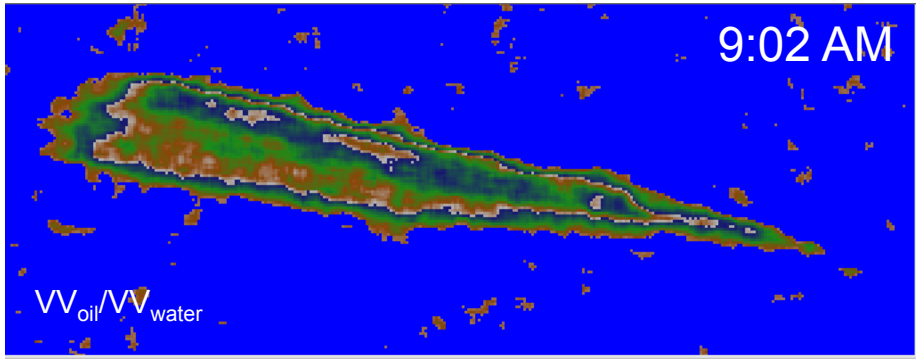
NORSE2015, Day 3

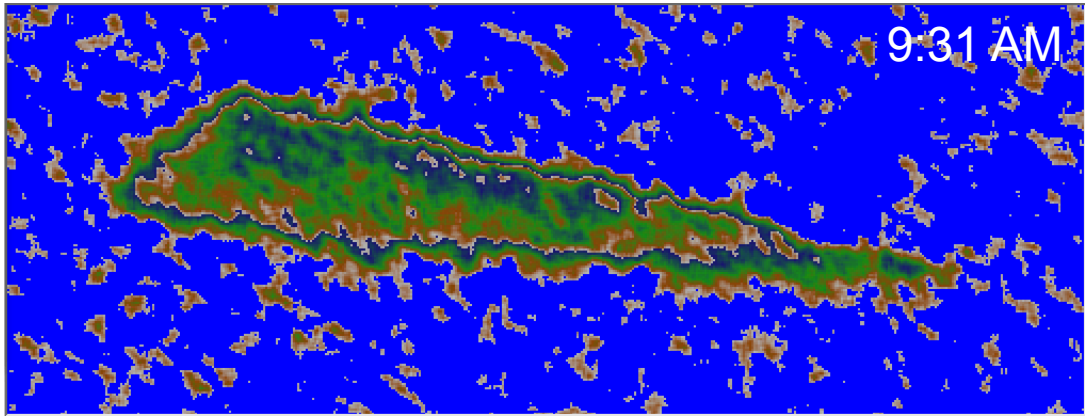
NORSE2015: Norwegian Spill Experiment (Day 3. 11 June 2015)

Release of 16 m^3 of emulsion into a boom

Photo: Øyvind Breivik (Met).

Unrecovered Oil Plume:





Summary

Low-noise SAR:

- **Characterize oil within a spill**
- **Use radar backscatter and temporal development of the slicks**
- **Qualitatively relate to volumetric fraction of oil for a thick layer**
- **Relate intensity to zones with more oil coverage**
- **Infer thickness from oil fraction for emulsions**
- **Infer % coverage and zoning from polarimetric or radiometric parameters**
- **Quantify separability of slicks from clean water and different types of slicks from each other**